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In re application of:
Hector Fillipus Alexander Van Drentham SUSMAN

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Filing Date: November 18, 2003

Examiner: Frank Tsay

For: DOWNHOLE TOOL

Attorney Docket No.: 85170-5000

SUBMISSION OF PRIORITY DOCUMENT

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Sir:

Applicants have claimed priority under 35 U.S.C. § 119 of Great Britain Application No. 0112261.3 filed May 19, 2001. In support of this claim, a certified copy of said application is submitted herewith.

No fee or certification is believed to be due for this submission. Should any fees be required, however, please charge such fees to Winston & Strawn LLP Deposit Account No. 50-1814.

Respectfully submitted,

5-5-06
Date

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Request for grant of a patent

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1. Your reference

   DM/RO/HSo/P10677GB

2. Patent application number *(The Patent Office will fill in this part)*

   0112261.3 19 MAY 2001

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   ROTECH HOLDINGS LIMITED
   WHITEMYRES AVENUE
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   AB16 6HQ
   UNITED KINGDOM

   Patents ADP number *(if you know it)*

   If the applicant is a corporate body, give the country/state of its incorporation

   UNITED KINGDOM 7898154001

4. Title of the invention

   DOWNHOLE TOOL

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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   SCOTLAND
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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
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DOWNHOLE TOOL

The present invention relates to a downhole tool. In particular, but not exclusively, the present invention relates to a downhole tool for generating a longitudinal mechanical load; and a drilling assembly, a rotary drill string and a downhole hammer assembly comprising or including a downhole tool for generating a longitudinal mechanical load.

Existing downhole tools used for generating a longitudinal mechanical load, typically known as impact hammers, are designed primarily for the installation and\or retrieval of downhole assemblies, for example, nipples. Such existing hammers tend to be either structurally very simple with consequent poor performance or tend to be structurally very complicated, with a large number of co-operating moving parts. An example of a hammer of the structurally simple type is the so-called Plotsky type hammer. This makes use of fluid swirls to develop a hammer action, where a fluid swirl is developed downstream of a nozzle in a fluid flow path. When the swirl breaks up, the fluid velocity decreases, causing an increase in the fluid pressure, which moves a piston in a percussive hammer action as the swirl builds up and breaks repeatedly. As noted above however, this results in poor performance of the hammer and is difficult to control. Disadvantages

associated with the structurally complex hammers include that the hammers are difficult and expensive to manufacture, assemble and maintain.

It is amongst the objects of embodiments of the present invention to obviate or mitigate at least one of the foregoing disadvantages.

According to a first aspect of the present invention there is provided a downhole hammer comprising:

a first member, a second member and sealing means between said first and second members, wherein, in use, application of fluid pressure to the hammer causes the first and second members to move from respective first to respective second positions and during such movement the sealing means sealing between the first and second members substantially prevents fluid flow therebetween, and

wherein further, in use, further application of fluid pressure causes the sealing means to release, to allow the second member to return to the first position whereby the second member is impacted by a remainder of the hammer.

According to a second aspect of the present invention, there is provided a downhole tool for generating a mechanical load, the tool comprising:

a generally hollow housing;

first and second members each disposed at least partly in the housing and movable with respect to the housing between respective first and second positions in response

to an applied fluid pressure;

sealing means for sealing between the first and second members during movement of the members from the respective first to the respective second positions; and

restraint means for restraining movement of the first member relative to the second member so as to cause the sealing means to release, to allow fluid flow between the first and second members;

whereby such fluid flow allows the second member to return to the first position, to impact the first member and generate the mechanical load.

According to a third aspect of the present invention, there is provided a drilling assembly comprising a drilling motor and a downhole hammer in accordance with the first aspect of the present invention, or a downhole tool in accordance with the second aspect of the present invention.

According to a fourth aspect of the present invention, there is provided a rotary drill string including a downhole hammer in accordance with the first aspect of the present invention, or a downhole tool in accordance with the second aspect of the present invention.

According to a fifth aspect of the present invention, there is provided a downhole hammer assembly including a downhole hammer in accordance with the first aspect of the present invention, or a downhole tool in accordance with the second aspect of the present invention.

In this fashion, a downhole tool may be provided which allows for a mechanical load to be generated downhole. It will be understood that references to a mechanical load are to a load generated by the tool which may be transmitted by, for example, a mechanical connection or coupling, to transmit the load to a secondary object or tool located downhole. It will further be understood that the mechanical load is preferably directed longitudinally through the tool and through a borehole in which the tool is located. In particular, the downhole tool comprises an impact hammer for use in downhole operations, which generates a mechanical load in the form of a percussive impact caused by fluid flowing through the tool.

The downhole tool may be provided as part of a drilling assembly including a drilling motor. Typically, the drilling assembly is run on coiled tubing, however, the assembly may alternatively be run on a drill string comprising sections of connected tubing, or the like. Alternatively, the downhole tool may be provided as part of a rotary drill string. In this fashion, the downhole tool may be utilised to provide a percussive drilling effect or "hammer effect". The combination of impact and rotation of a drill bit coupled to the tool advantageously results in a higher rate of penetration and material removal than would be experienced with either impact or rotation alone.

In a further alternative, the downhole tool may be

provided as part of a downhole hammer assembly for hammering assemblies into place downhole and\or to dislodge assemblies to allow retrieval. Typically, the downhole hammer assembly is run at an end of coil tubing or a drill string.

The present invention is particularly advantageous in that the downhole tool, including the first and second longitudinally movable members, is simple to manufacture, assemble and maintain, and functions simply and reliably, without an excessive number of moving parts, to achieve the desired aim of generating a mechanical load. Furthermore, the present invention is advantageous over downhole tools which function with fewer parts, in that it allows the mechanical load to be reliably generated and for the load to be initiated when desired on reaching predetermined threshold values of certain parameters. In particular, such threshold parameters may include the applied fluid pressure and the Weight On Bit (WOB), that is, the force exerted on a drill bit (where the downhole tool is provided as part of a drilling assembly or a rotary drill string) through the drill string or the like.

Preferably, the second member is movable to a third position, where fluid flow is permitted between the first and second members and through the generally hollow housing. Such fluid may then flow, for example, to a drill bit to remove drill cuttings from a borehole, or may be

circulated through a borehole. Preferably also, the first member is adapted to return to its first before impacting the second member, such that the weight of at least part of the tool and/or a string carrying the tool and/or WOB is directed through the first and second members.

The tool may further comprise a turning mechanism for rotating at least a part of the tool relative to the remainder of the tool. The turning mechanism may comprise a first mechanism part coupled to the second member of the tool, a second mechanism part for coupling to a secondary member to be rotated, and an intermediate mechanism part, coupled to the tool housing and serving for rotating one or both of the first and second mechanism parts.

Preferably, the generally hollow housing defines an internal bore in which the first and second members are disposed for longitudinal movement therein. The housing may be coupled at one end to a first generally tubular member which may take the form of a top sub. The first generally tubular member may define an internal bore, an end of which is adapted to slidably receive at least part of the first member for locating the first member in the housing. The housing, in particular the internal bore of the first generally tubular member, may define or include a flow restriction which may take the form of a nozzle. The flow restriction may be disposed adjacent an end of the first member.

Fluid may be supplied to the downhole tool through a drill string, coil tubing or the like, and the fluid may typically comprise a drilling fluid such as a drilling mud.

The sealing means may comprise respective seal faces of the first and second members, the seal faces being selectively biassed into sealing abutment when the first and second members are in the respective first and second positions and\or moving between the first and second positions, to seal between the first and second members. The first and second members may be biased by biassing means, such as springs, towards their respective first portions.

The first member preferably comprises a generally tubular shuttle valve defining an internal bore. One end of the shuttle valve may define a seal face for sealing abutment with the second member. One or more flow ports may be defined through a wall of the first member to selectively allow fluid flow through the first member, and in particular, through the bore and out of the shuttle valve.

The housing may define a chamber or area in fluid communication with the first member through the one or more flow ports, to selectively receive fluid from the first member. Furthermore, the chamber or area may be in selective fluid communication with the second member, to allow fluid flow between the first member and the second

member through the chamber or recess. The housing may include one or more ports, such that part of the housing experiences external fluid pressure, in particular the pressure of fluid in a borehole. Preferably, one end of the second member experiences external fluid pressure, to allow a pressure differential to be generated across the second member. This may allow the second member to move in response to applied fluid pressure.

The second member may comprise a generally tubular piston defining an internal bore. The bore may be sealed by the sealing means to prevent fluid flow therethrough, when the first and second members are in or moving from their respective first to their respective second positions.

The downhole tool may include a coupling for coupling the second member to a secondary member such as, for example, a length of drill tubing, a drill bit, or an assembly to be hammered into place\dislodged. The coupling may comprise a bit box.

The mechanical load may be generated in the following fashion: fluid is passed down a drill string, coil tubing or the like to the downhole tool, through the bore of the top sub and the nozzle and into the internal bore of the shuttle valve, exiting through the one or more flow ports into the area or chamber defined by the housing. This applies pressure to an upper face of the piston; the front

or lower face is exposed to annulus pressure. This pressure differential creates a force which moves the piston longitudinally forwards relative to the housing; in effect, the housing moves back away from the piston. As the piston moves relatively forwards, the shuttle valve is pushed relatively forward, due to the increased pressure behind it. Initially, the shuttle valve is sealed relative to the piston by engagement of the seal faces between the valve and the piston such that fluid does not flow from the shuttle valve to the piston. Both the valve and piston are brought to their respective second positions. The shuttle valve is then restrained from further longitudinal movement with the piston. The piston is then forced relatively longitudinally away from the shuttle valve, such that the seal is released, allowing fluid to flow from the valve to the piston and through the piston bore. This causes the fluid pressure to drop, and the shuttle valve can return to its first position. The piston then rapidly returns to its first position, impacting the shuttle valve and generating the mechanical load. In effect, the housing slams down onto the piston to impact the shuttle valve against the piston. The fluid pressure once again increases until the piston is again forced away, and repetition of this process imparts the mechanical load or percussive "hammer" action.

Conveniently, the restraint means comprises part of the housing, and may comprise a shoulder on an inner wall

of the housing adapted to abut and restrain the first member in the second position. It will be understood that the first member is restrained from longitudinal movement beyond the second position in a direction towards the second member, but may move longitudinally away from the second member under forcing action of the biassing spring, when the fluid pressure decreases sufficiently. The shoulder may comprise a substantially radially inwardly extending shoulder for abutting a co-operating outwardly extending shoulder on the first member.

In an alternative embodiment, the downhole tool may further comprise a key assembly for restraining the second member against rotation with respect to the housing. The key assembly may comprise a key located between an inner surface of the housing and an outer surface of the second member. The key may engage keyways in both the second member and the housing. This may allow the piston to slide longitudinally with respect to the housing without relative rotation.

It will be understood that references herein to longitudinal movement are to movement generally in a direction of a main or longitudinal axis of the downhole tool.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figs. 1A to 1D are longitudinal cross-sectional views of a downhole tool in accordance with a preferred embodiment of the present invention, shown at various stages of a cycle in which the tool generates a mechanical load;

Figs. 2A and 2B are perspective views of one embodiment of a turning mechanism forming part of the tool of Figs. 1A to 1D; and

Figs. 3A and 3B are perspective views of an alternative turning mechanism forming part of the tool of Figs. 1A to 1D.

Referring initially to Figs. 1A to 1D, there is shown a downhole tool for generating a longitudinal mechanical load, the downhole tool taking the form of an impact hammer indicated generally by reference numeral 10. The impact hammer has two main functions; firstly, it can be used as part of a drilling assembly (not shown) comprising a drilling motor or a rotary drill string (not shown) including the impact hammer 10, to provide a percussive drilling effect or "hammer effect". The drilling assembly would typically be run on coil tubing, whilst the rotary drill string, as will be appreciated by persons skilled in the art, typically comprises lengths of inter-connected drill tubing.

Secondly, the impact hammer 10 may be used on its own as a device to hammer assemblies into place downhole or to

dislodge them to allow retrieval. In this case, the impact hammer 10 is typically run on the end of a coil tubing rig or a drill string.

The impact hammer 10 comprises a generally hollow housing 12; first and second members, in the form of a shuttle valve 14 and a piston 16, respectively, disposed in the housing 12 and movable longitudinally with respect to the housing; sealing means for sealing the shuttle valve 14 to the piston 16, in the form of seal faces 18 and 20 of the valve 14 and the piston 16, respectively; and restraint means in the form of a stop shoulder 22 for restraining the shuttle valve 14.

As will be described in more detailed below, the shuttle valve 14 and piston 16 are movable longitudinally within the housing 12 between respective first and second positions; in Fig. 1A, the valve 14 and piston 16 are shown in their first positions. In their first positions, and indeed, during movement between the first and second positions (Fig. 1B), the shuttle valve 14 and the piston 16 are in abutment, where the seal faces 18 and 20 seal the valve 14 to the piston 16, such that fluid flow therebetween is prevented. The shuttle valve 14 and piston 16 are moved between their first and second positions in response to an applied fluid pressure, and when the valve 14 and piston 16 are in their second positions (Fig. 1B), fluid pressure moves the piston 16 away from the valve 14

(Fig. 1C) causing the seal between the seal faces 18 and 20 to release. This allows fluid to flow between the valve 14 and the piston 16, reducing the fluid pressure, such that the valve 14 returns to its first position (Fig. 1D). The piston 16 is then also returned rapidly to its first position, impacting with the first member (Fig. 1A) to generate the mechanical load. This cycle is then repeated to generate a cyclical or "percussive" impact through the tool 10.

In more detail, and describing the impact hammer 10 top-to-bottom, the hammer 10 includes a top sub 24 having a tapered screw connection 26 for coupling the hammer 10 to, for example, coil tubing, a drill string or the like, as described above. The top sub 24 defines an internal through-bore 28 for the passage of fluids such as a drilling fluid, typically in the form of drilling mud, from coiled tubing and the like coupled to the hammer 10. A flow restriction in the form of a nozzle 30 is provided in the bore 28 and acts as a restriction to flow of fluid through the bore. A lower part 32 of the bore 28 receives the shuttle valve 14 in a sliding engagement, as will be described below. The top sub 24 is coupled to the hollow housing 12 by a cylindrical threaded connection 34, and defines an upper end of the impact hammer 10.

Turning now to the shuttle valve 14, the valve 14 includes a shuttle 36 which is generally tubular, defining

an internal bore 38. An upper end 40 of the shuttle 36 is mounted in the lower part 32 of the bore 28. A locating ring 42 is provided within the housing 12 and defines the stop shoulder 22, which both acts as a restraint for the shuttle valve 14 and acts as a guide for the valve 14 during its sliding longitudinal movement.

A lower end of the shuttle 36 defines the seal face 18, and an angled port 44 allows for fluid flow through the bore 38 and out of the shuttle 36. Biassing means are provided in the form of a biassing spring 46, mounted on the shuttle 36 and acting between the locating ring 42 and a shoulder 48 on the shuttle 36. This spring 46 serves to bias the shuttle 36 into abutment with the top sub 24, in the absence of applied fluid pressure. For a 3⅛" impact hammer, the spring 36 is typically of a free length of 3", a compressed length of 1.6" and of an outside diameter of 2.080". The spring force is 100lbs, the wire diameter 0.175", with 4 coils and a spring rate of 70lbs/in.

The shuttle valve 14 is disposed with the main part of the shuttle 36 in a chamber 50 defined by the housing 12, with an area 52 adjacent to the hole 44. The area 52 is defined by a radially extending shoulder 54 of the housing 12 and allows pressure equalisation between the chamber 50 and a further chamber 58 defined by the housing 12.

The piston 16 is generally tubular, defining an internal through-bore 60 for the passage of fluid. Sliding

seals 62 are provided at an end of the piston 16 adjacent the shuttle valve 14, for sealing the piston 16 in the housing 12. Biassing means are provided in the form of a biassing spring 64, mounted on the piston 16. The spring 64 has a free length of 3.5", a compressed length of 2.5" and is of an outside diameter of 2.609". The spring force is 340lbs, the wire diameter is 0.280", with 5 coils and a spring rate of 214lbs/in to normally bias the piston 16 towards the shuttle valve 14. This brings the seal faces 18 and 20 into abutment, in the absence of applied fluid pressure. Pressure equalisation ports 70 extend through the wall of the housing 12 to equalise pressure between an annular chamber 72 in which spring 74 is located, and the borehole, to allow movement of the piston 16. The ports 70 and area 52 thus prevent hydraulic lock-up of the shuttle valve 14 and piston 16 in use, during movement between their first and second positions.

A piston mounting assembly 66 is provided at the bottom of the housing 12 for mounting the piston 16 in the housing and for supporting it during its movement between the first and second positions. The mounting assembly 66 includes a collar 74 which is secured inside the housing 12 and sealed to the piston 16. A lower end 76 of the piston 16 is coupled to part of a turning mechanism 78 which rotates part of the tool 10 in use, as will now be described.

The turning mechanism 78 is shown in more detail in the perspective views of Figs. 2A and 2B, and generally includes a first mechanism part in the form of tube 80, a second mechanism part in the form of a coupling tube 82 and an intermediate mechanism part in the form of sub 84. As shown in the cross-sectional view of Figs. 1A-1D, the coupling tube 82 carries a bit box for coupling the tool 10 to a length of drill string, drill bit or the like. The coupling tube 82 is slidably mounted in the sub 84 and is threaded to the tube 80 at an upper end 88, and the tube 80 is itself threaded to the lower end 76 of the piston 16. Thus, it will be understood that during the above described movement of the piston 16, the tube 80 and coupling tube 82 are moved together with the piston 16.

The turning mechanism 78 is mounted in an extension 12a of the tool housing and the sub 84 is in turn mounted to the lower end of the housing extention 12a, with a further extention 12b mounted to the lower part of the sub 84 and sealed to the coupling tube 82, to prevent fluid ingress into the tool 10.

As shown particularly in Figs. 2A and 2B, the tube 80 carries a set of angled teeth 90 and the coupling tube 82 carries a set of castellated teeth 92. The sub 84 carries corresponding sets of angled teeth 90a and castellated teeth 92a which are selectively meshed with the teeth 90 on tube 80 and the teeth 92 on coupling tube 82, when the

piston 16 is moved within the tool 10 as described above.

Only one set of the teeth 90/90a or 92/92a are meshed at any one time. Furthermore, the sets of teeth 90/90a and 92/92a are offset with respect to one another such that selective meshing of one of the sets 90/90a or 92/92a causes a corresponding rotation of the tube 80 and the coupling tube 82. In particular, the castellated teeth 92/92a are profiled and arranged on the turning mechanism 78 so as to provide an 18° rotation of the tube 80 and the coupling tube 82, when meshed. On the other end, the angled teeth 90/90a are profiled and arranged on the mechanism 78 to provide a 6° rotation when meshed. Thus, a sequential meshing of the respective sets of teeth provides a total 24° rotation, therefore fifteen such sequencial meshings of the sets of teeth provides a complete, 360° rotation of the tube 80 and the coupling tube 82.

The sets of teeth 90/90a and 92/92a are sequentially meshed as shown in Figs. 1A to 1D. As described above, in Fig. 1A, the piston 16 is in its first position, where the teeth 92/92a are fully meshed, and the teeth 90/90a are fully separated. Movement of the piston 16 to its second position (Fig. 1B) moves the teeth 92/92a apart and meshes the teeth 90/90a, providing a 6° rotation of the coupling tube 82, under the forcing action of the fluid flowing through the tool 10. The teeth are fully meshed when the tool 10 is in the position of Fig. 1C, following which the

piston 16 returns to the position of Fig. 1A, fully meshing the teeth 92/92a and separating the teeth 90/90a, to provide an 18 degree rotation of the coupling tube 82. Thus, it will be understood that fifteen such cycles of the tool 10 between the position of Fig. 1A and the position of Fig. 1C provides the 360° rotation of the coupling tube 82.

Furthermore, it is preferred that the greatest degree of rotation and thus the location of the teeth 92/92a, be provided during movement of the piston 16, and thus the coupling tube 82, towards the piston first position (Fig. 1A). This is because the large, rapidly applied WOB acts to mesh the teeth 92/92a, to provide the greater rotation. This is in contrast to the relatively slowly increasing fluid pressure moving the piston 16 downwardly.

An alternative embodiment of a turning mechanism is shown in Figs. 3A and 3B, and indicated by reference numeral 178. In this embodiment, teeth 190/190a are provided on the coupling tube 182, whilst teeth 192/192a, similar to the castellated teeth 92/92a, are provided on the tube 180. The teeth 192/192a provide an 18° rotation of the tube 180 and the coupling tube 182 on the downward stroke of the piston 16, that is, towards the position of Fig. 1C. Also, the sub 184 includes two flats 94, which allow the sub 184 to be engaged by a spanner and separated from the tool 10, if required.

Operation of the impact hammer 10 to achieve a

percussive mechanical load is achieved in the fashion which will now be described. The impact hammer 10 is made up to a string and run into a borehole, typically a casing lined borehole, in which the desired well operation is to be carried out. In this embodiment, the operation will be described in relation to a rotary drill string carrying a drill bit (not shown), where the mechanical load is to be applied to the bit by the impact hammer 10.

Fluid is pumped through the string into the bore 28 of the top sub 24 and is accelerated through the nozzle 30. This increases the velocity and reduces the pressure of the fluid, to assist in movement of the shuttle valve 14. The fluid passes through the nozzle 30, and into the bore 38 of the shuttle valve 14, and subsequently exits through the hole 44 into the area 52 in the housing 12. At this point, the seal face 18 of the shuttle valve 14 and the seal face 20 of the piston 16 are in contact, providing a seal to prevent the passage of fluid therebetween. As fluid fills the area 52, its pressure increases as there is no route for escape of the fluid. This in turn applies pressure to the seal face 20 of the piston 16. A front face 96 of the piston 16 is subjected to lower pressure through the ports 70 such that the front face of the piston is exposed to annulus pressure.

This pressure differential produces a force which causes the piston 16 to move rapidly relative to the

housing 12. As the piston 16 moves relatively forward, the shuttle valve 14 is pushed forward with it, due to the increased pressure behind the valve 14, and this maintains the seal between the seal faces 18 and 20 of the two parts. In fact, the housing 12 moves up somewhat to accommodate this movement, as the drill bit is in contact with the rock strata being drilled. This motion continues until the shuttle 36 of the shuttle valve 14 contacts the stop shoulder 22 on the locating ring 42 (Fig. 1B). At this point, the fluid can start to flow between the seal faces 18 and 20 of the shuttle valve 14 and 16 respectively, and into the piston bore 60 (Fig. 1C), and the teeth 90/90a have fully meshed, providing a 6° rotation of the coupling tube 82, and thus of the drill bit.

As a consequence, the pressure in the housing 12 drops, and the shuttle valve 14 is returned to its original position by the spring 46. The fluid can exhaust through the piston bore 60 and out through ports in the drill bit, in a fashion known in the art. The housing 12 then moves rapidly down to slam the piston 16, impacting the shuttle valve 14 against the piston, thus returning the piston to its original position (Fig. 1A). The teeth 92/92a have then fully meshed, providing an 18° rotation of the coupling tube 82 and the drill bit. The cycle then repeats to achieve the percussive hammer effect.

The action is initiated by application of some

hydraulic load to the bit, which ensures that the shuttle valve 14 and piston 16 have an initial seal (between seal faces 18 and 20) to start the impact cycle. The impact hammer will start impacting at a particular Weight On Bit (WOB) depending on the geometry of the above-described components. Further, there is a range of average WOB over which the device will function. The characteristics of the impact hammer 10 may be tuned to particular applications by modification of the geometry of the fluid components and the spring rates. In particular, the following effects have been found by the inventors to hold:

increase of the spring rate of the piston spring 64 within a certain range of parameters decreases the range of WOB over which hammering occurs;

increase of the spring rate of the shuttle valve spring 46 will increase the WOB to initiate action and increase the range;

increase of the diameter of the shuttle bore 38 will increase the range of flow over which the hammer action occurs;

smoothing the flow path in the shuttle to reduce losses increases the WOB to initiate hammering, increases the range over which hammering occurs and reduces back pressure to drive the impact hammer 10;

increase of flow rate of fluid increases the impact frequency and impact force and produces a slight increase

in WOB to initiate hammering;

the rate of impact can be modified by the flow rate and the rates of the springs and the weight, while increasing the pre-load of the piston spring 64 generally reduces WOB at which impact will be initiated;

decreasing the nozzle 30 diameter increases the WOB to initiate hammering but increases back pressure;

removal of the nozzle 30 may result in no hammer action being produced; and

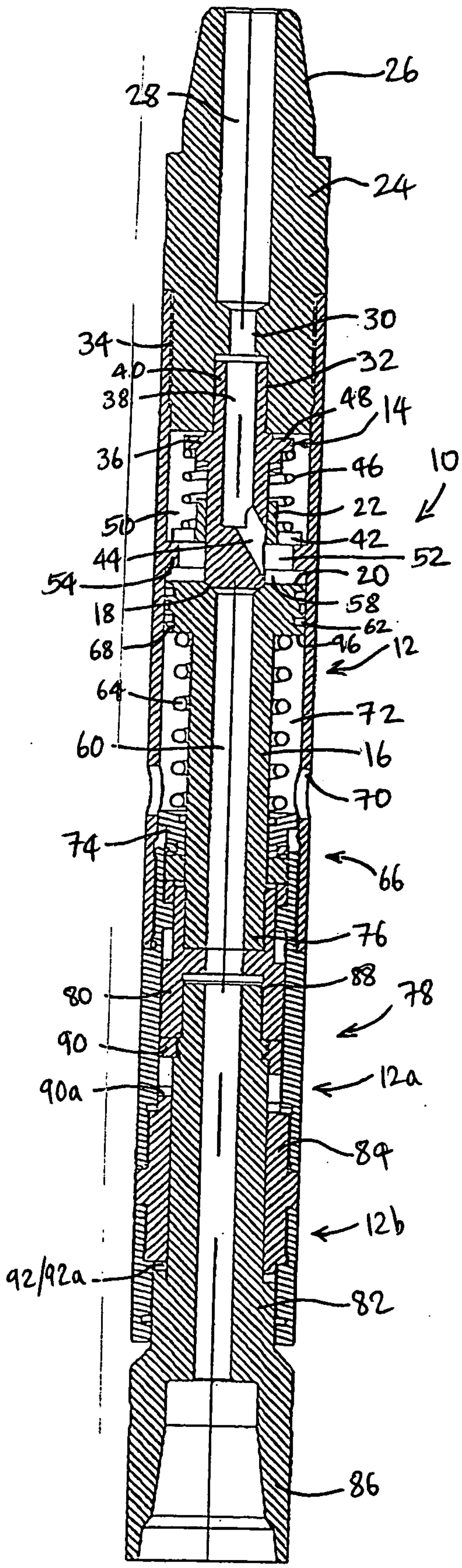
positioning the nozzle 30 further upstream of the shuttle valve 14 decreases the WOB to initiate hammering.

In addition, it is believed that a decrease in the piston seal face 20 area will decrease the impact force and the WOB to initiate impact.

Various modifications may be made to the foregoing within the scope of the present invention.

For example, the nozzle 30 may be provided as a separate component, such as a tubular insert for location in the bore 28. The piston 16 may include an integral coupling.

The tool may be provided without a turning mechanism, to provide a straight, non rotary impact. In this event, the tool may include a key mechanism, for preventing rotation of the piston 16. There may be a plurality of ports 44 in the shuttle valve 14, and the ports may be radially or otherwise directed.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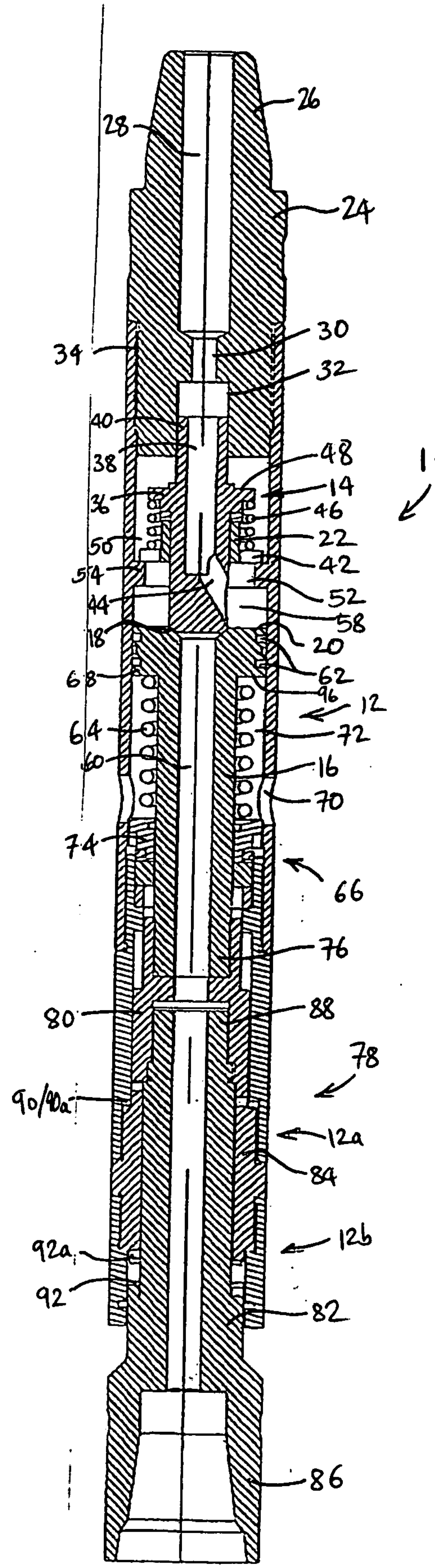
12a
84
12b
92/92a
82
86

FIG1A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76
80
88
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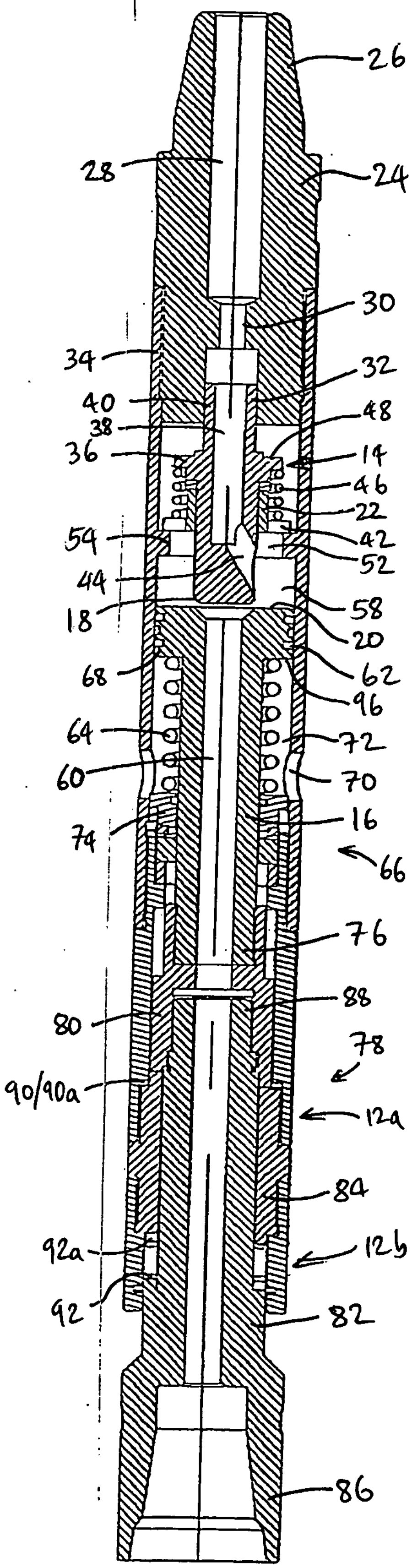
90/90a
12a
84
92a
12b
92
82
86

FIG1B



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12b
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FIG 1C

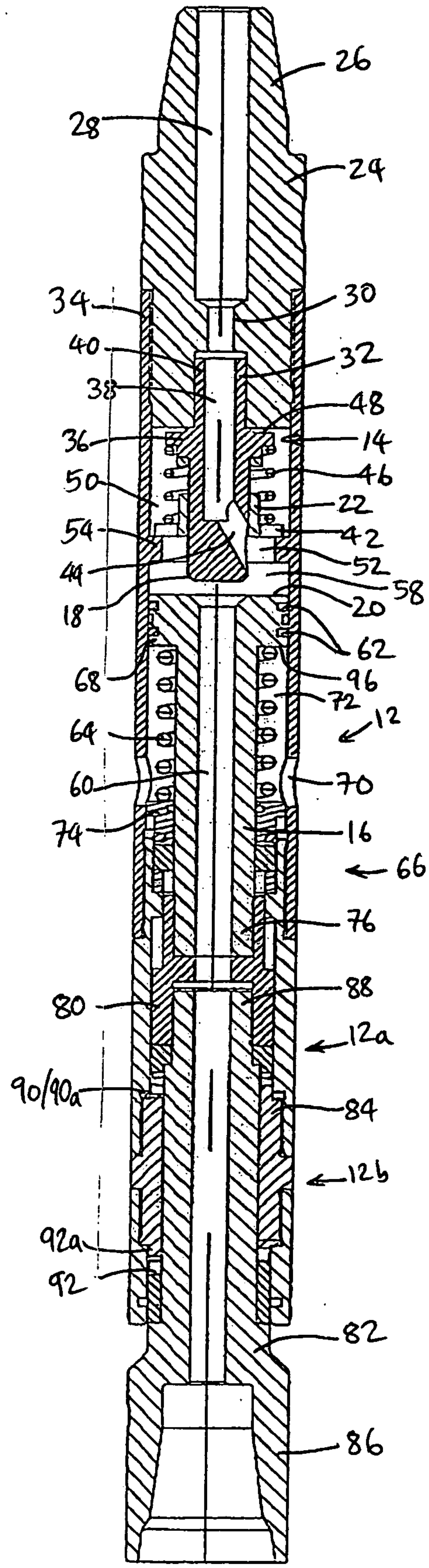

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FIG 1D

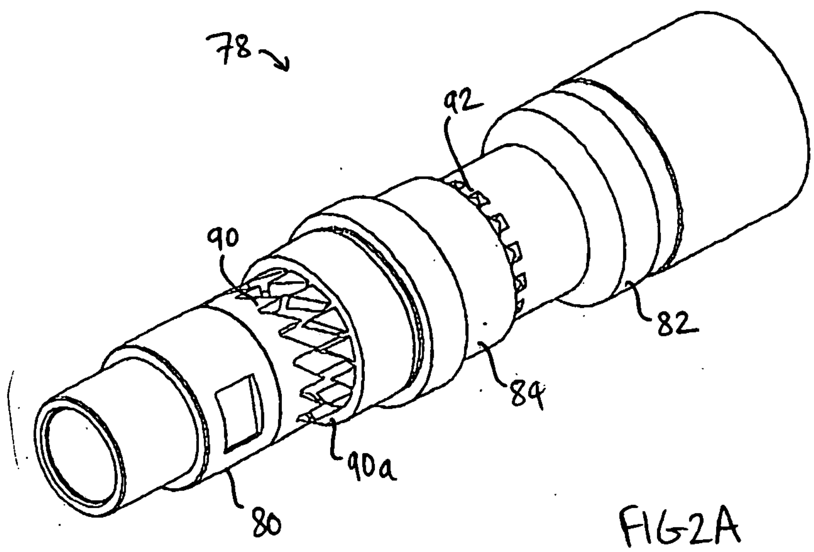


FIG 2A

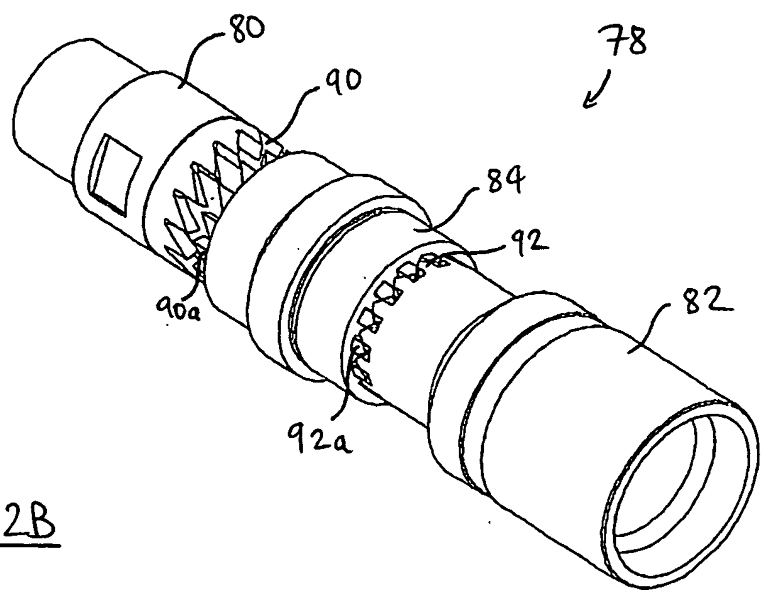
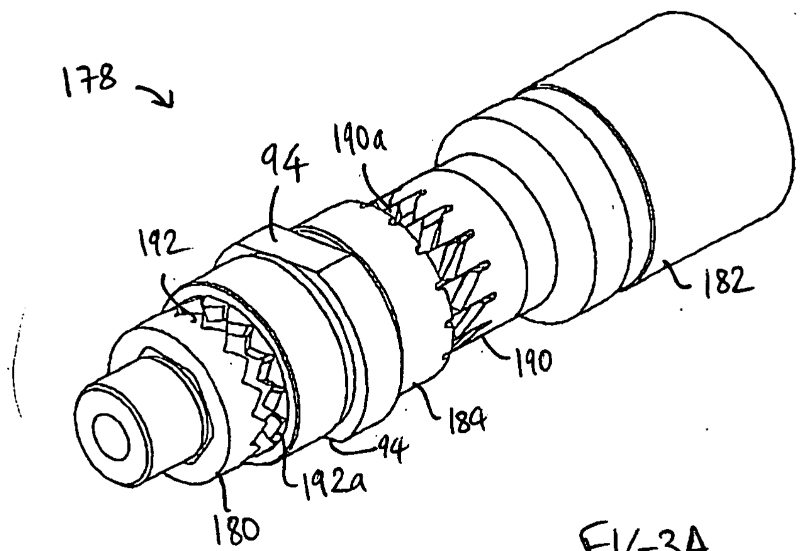


FIG 2B


178
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184
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192a
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FIG3A

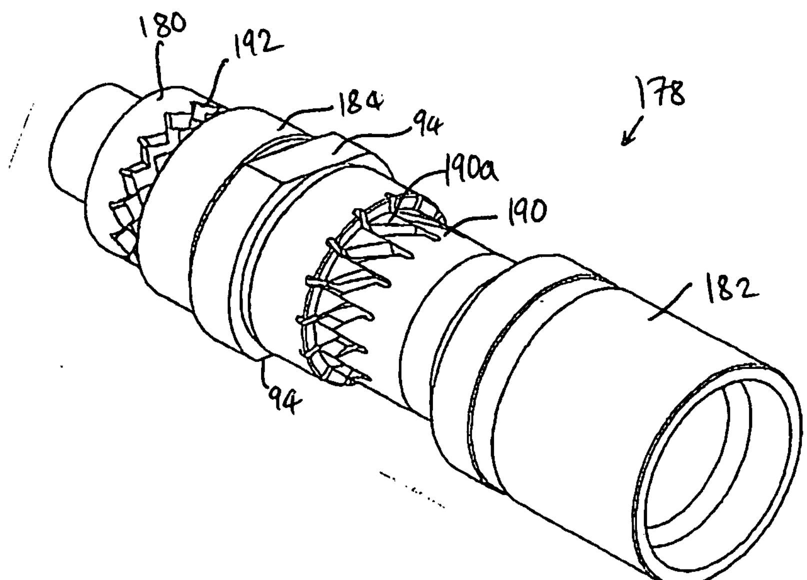
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FIG3B